METHOD AND APPARATUS FOR CONNECTING AN IP-BASED CLIENT TO A SERVER THROUGH AN OSI NETWORK

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This is the first application filed for the present invention.

MICROFICHE APPENDIX

[0002] Not applicable.

TECHNICAL FIELD

[0003] The invention relates to data transport over an Open System Interconnection (OSI) network and, in particular, to a method and apparatus for transporting IP packets over an OSI network to link IP-based devices.

BACKGROUND OF THE INVENTION

[0004] In recent years, optical networks that operate under the OSI protocol have used complicated hardware and software that is located remotely from a network operation center (NOC). Personnel, such as field engineers, need consolidated system information for tuning new equipment or running maintenance on equipment at remote locations. Full-scale access to an operation center helps reduce the time required to install and maintain network equipment. Field engineers typically work in small regions, usually at a central office, but they remote access to network management facilities in order to be efficient. Access today is done through a serial port on a laptop using a TCP/IP protocol. Modems are not always available at remote sites, where phone lines are frequently required for voice communications. Mobile phone modem access may solve the

problem of communication, but cannot provide sufficient transfer speeds to support data connections. The absence of LAN connectivity and phone access often forces field engineers to use the phone lines in hotel rooms or the like to achieve sufficient speed of connection.

[0005] The most logical and effective way for connecting with system management facilities is an Ethernet connection between the optical network and a field engineer's computer. Ethernet connections provide sufficient data transfer speed, but the use of different communications protocols and hardware connectivity problems prevent Ethernet connections from being available at all remote network element sits. Furthermore, many network elements do not have an Ethernet interface, so Ethernet connectivity would require new hardware deployment and incur extra cost for customers. Another solution is an IP to OSI gateway that could translate IP client packets to OSI protocol and vice versa. Such a gateway is difficult to design, due to the nature of the complex infrastructure of the network management facilities.

[0006] Consequently, there is a need for a cost-effective solution that can provide a TCP/IP connection between a remote computer and network management facilities without deployment of new hardware or installation of complicated software on network elements or network management facilities.

SUMMARY OF THE INVENTION

[0007] It is therefore an object of the invention to provide a simple, cost-effective solution for transferring IP packets through an OSI network between an IP client and an IP server.

[0008] It is a further object of the invention to provide a solution for transferring IP packets through an OSI network that does not require an addition of new hardware.

[0009] In accordance with a first aspect of the invention, there is provided apparatus for connecting IP-based devices through an OSI network that includes a plurality of network elements, comprising: a plurality of OSI network elements interconnected by at least one optical fiber for transmitting information through the network using OSI packets; at least first and second network elements having a TCP/IP interface for sending and receiving IP packets; a table containing information about addresses of IP packets that are received and sent, an OSI address of OSI packets that encapsulate IP packets that are received and sent and a timestamp associated with each record in the table, the timestamp representing a time of sending an OSI encapsulated IP packet to an address in the record; an application adapted to originate the destination OSI address of a network element associated with an IP destination address of an IP packet, encapsulate the IP packet in an OSI packet, remove an IP packet from an OSI packet, and maintain the table.

[0010] In accordance with a second aspect of the invention, there is provided a method for connecting IP-based devices through an OSI network having a plurality of network elements, comprising steps of: receiving at a first network element a first IP packet to be sent via the OSI network to a second network element that is adapted to deliver the first packet to an IP destination address in the IP packet; encapsulating the first IP packet in an OSI packet and broadcasting the OSI packet to each network element that supports a TCP/IP gateway; receiving the OSI

packet at each of the network elements, recording an OSI origination address extracted from the OSI packet, removing the encapsulated IP packet, and recording the IP origination and destination addresses; forwarding the IP packet over a TCP/IP link supported by the TCP/IP gateway.

[0011] The invention therefore permits IP packets to be transferred through the OSI network without the addition of hardware. In one embodiment of the invention, the IP packets are encapsulated in connectionless network protocol (CLNP) OSI packets, and a special value is inserted into a network layer selector (NSEL) to permit a receiving network element to efficiently discriminate OSI packets that encapsulate IP packets.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] Further features and advantages of the present invention will become apparent from the following detailed description, taken in combination with the appended drawings, in which:

[0013] FIG. 1 is a schematic diagram of an optional network that can be adapted to provide IP packet transmission between two IP devices that are coupled to the optical network;

[0014] FIG. 2 is a schematic diagram illustrating the optical network shown in FIG. 1 originating a destination address of a network element that serves an IP device having the destination address of the IP packet.

[0015] FIG. 3 is a schematic diagram illustrating the optical network shown in FIG. 1 that is returning a response IP packet to the source IP device;

[0016] FIG. 4 is a schematic diagram of an OSI packet that encapsulates an IP packet;

[0017] FIG. 5 is a schematic diagram of a look-up table maintained by network elements of the optical network; and

[0018] FIGs. 6A and 6B are a flowchart of principal steps that are performed by network elements when transmitting IP packets through the OSI optical network.

[0019] It will be noted that throughout the appended drawings, like features are identified by like reference numerals.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0020] The present invention permits IP packets to be transferred through an OSI optical network to enable an IP exchange between two IP devices coupled to the OSI network.

[0021] FIG. 1 schematically depicts an exemplary optical network 100 that operates under the Open System Interconnection (OSI) protocol. The optical network 100 includes a number of network elements 104, 106, 108, 110 and 112 connected directly or indirectly to each other by optical fibers 114. The optical network 100 may include a large number of network elements that are geographically distributed across a large territory. Each network element has its own OSI address and supports data exchange with other network elements 104, 106, 108, 110 and 112 of the optical network 100 using the OSI protocol. Under the OSI protocol, the data exchange occurs using data packets. In the example shown in FIG. 1, the optical network 100 supports a data exchange between a client computer 118 and a network management server 120. Each has an Ethernet TCP/IP connection, or any other connection medium that

supports a TCP/IP connection to the optical network. The client 118 and the network management server 120 also have unique IP addresses.

[0022] Each network element 104, 106, 108 and 110 functions identically to transmit and route data through the optical network 100. The network elements 104, 106, 108, 110 and 112 may also support a variety of interfaces for the connection of external devices. For example, the network elements 108 and 110 support gateways for Ethernet TCP/IP connections. The network element 104 has an Ethernet TCP/IP interface. The network elements 106 and 112 may also support an Ethernet TCP/IP interface.

[0023] The optical network 100 is managed by a network management application that monitors network resources, provides operative management of the network resources, tracks network status, posts alarms for network management personnel when abnormal conditions are detected in the optical network 100, and facilitates other functions related to the optical network management.

[0024] The invention enables the delivery of data in TCP/IP format via the optical network 100 using the OSI protocol. The structure of a TCP/IP and an OSI packet are not identical. Consequently, a TCP/IP packet cannot be transferred through the optical network 100 as an IP packet.

[0025] As shown in FIG. 2, the client 118 sends an IP packet 130 that contains data to be delivered. In the example illustrated in FIG. 2, the destination address of the IP packet 130 is the IP address of the network management server 120. The IP address of the client 118 is automatically inserted as an origination address in the IP

packet 130. The network element 104 has, in addition to software that has the primary function of managing the transfer of OSI packets through the optical network 100, an application 132 that monitors and classifies all incoming packets from external sources. If an incoming packet is determined to be an IP packet, the packet is encapsulated into an OSI packet 132 that has to be delivered to the network element 110, which is connected to the network management server 120 that has an IP address that matches the destination address of the IP packet 130.

[0026] Prior to exchanging IP packets between the two IP devices, the client 118 and the network management server 120 in this example, the network element 104 has to originate the OSI address of the network element 110 that serves the network management server 120. In accordance with the invention, the network element 104 originates the OSI address of the network element 110 by encapsulating the received IP packet 130 in an OSI packet that is sent to each network element in the optical network 100 that supports a gateway 116. In the example illustrated in FIG. 2, the OSI packet 132 that encapsulates the IP packet 130 is broadcast to all of the network elements 106, 108, 110 and 112. Only the network elements 108 and 110 perform additional processing. Network elements 108 and 110 are adapted to extract the IP packet 130 from the OSI packet 132 and to send the IP packet 130 via the respective gateways 116. As an alternative, if broadcast capability is not available in the opticall network 100, a list 208 of OSI addresses of network elements that support a TCP/IP gateway can be maintained. In that case, the OSI packet 132 is sent only to those network elements in the list 208.

[0027] In accordance with an embodiment of the invention, the IP packets are encapsulated in connectionless network protocol (CLNP) OSI packets. As is known in the art, CLNP is a lower layer OSI protocol that carries upper-layer data and error indications. In order to facilitate discrimination of OSI packets that encapsulate IP packets, a predetermined network layer selector (NSEL) is inserted in a header of each OSI packet that carries an IP packet. This permits the CLNP packet to be forwarded through the OSI network using normal OSI routing mechanisms. As will be understood by persons skilled in the art, however, other delivery mechanisms can be used and the invention is not limited to the use of CLNP packets for delivery.

[0028] Each network element with a gateway 116 is provisioned with an application 204 for analyzing incoming packets from the OSI network 100. The incoming packets are classified. Each network element of the optical network 100 may receive OSI packets, IP packets, or packets of other types. A received OSI packet may be a standard OSI packet that has to be delivered to an OSI destination address, or an OSI packet that encapsulates an IP packet. The network elements 108 and 110 are adapted to remove an encapsulates IP packet from an OSI packet; extract the destination/origination addresses of the IP and OSI packets; write these addresses along with a timestamp as a record in a look-up table; and forward the IP packet via the gateway.

[0029] Only the network element 110 will receive an IP packet 302 (FIG. 3) in response to the IP packet 130 (FIG. 2), because the IP device which is the network management server 120 served by the network element 110 has the same IP address as the destination address of the IP

packet 130 (FIG. 2). When the response packet 302 is received at the network element 110 the application 204 determines that it is an IP packet and extracts the destination address of the response IP packet 302. The look-up table 210 of the network element is searched to locate the address of the network element that is associated with the destination address of the response IP packet 302. When the destination OSI address is located, the response IP packet 302 is encapsulated in an OSI packet 304 and the OSI destination/origination addresses are inserted in that OSI packet. Then the OSI packet 304 is forwarded to the destination address, and the timestamp is updated in the look-up table 210. If a matching address is not found in the look-up table 1210, the IP packet 302 is treated as described above and forwarded to all other network elements.

[0030] The OSI packet 304 having encapsulated the response IP packet 302 is forwarded to the destination address, which is, in the example illustrated in FIGs. 2 and 3, the network element 104.

[0031] The network element 104 receives the OSI packet 304 containing the response IP packet 302. That OSI packet 304 is segregated from the standard OSI packets transferred through the OSI network 102. The application 204 at the network element 104 removes the response IP packet 302 from the OSI packet 304, and extracts the destination/origination addresses of the IP packet 302 and the OSI packet 304. The look-up table 204 is searched for the origination/destination addresses of the response IP packet. If those addresses match a destination/origination address pair in the records of the look-up table 210, the origination address of the OSI packet 304 is written in the

record as an OSI destination address. At the same time, the timestamp in the record is updated. The next incoming IP packet having a destination address that matches the IP address of the network management server 120 is encapsulated in an OSI packet and set to the destination address that is specified in the look-up table 210. The two look-up tables 210 at the client side network element 104 and at the server side network element 110 provide the address information for IP packet exchange between two IP devices: the client 118 and the network management server 120. The applications 204 at the network elements 104 and 110 preferably also provide an option for controlling the bit rate of the IP packet exchange for protecting the resources of the optical network 100 from overflow. The bit rate can be determined by an administrator of the optical network 100. The bit rate of IP packet exchange is regulated by delaying processing of incoming IP packets at the receiving network element. In the preferred embodiment, the bit rate is regulated by delaying the processing of the IP packets by storing incoming IP packets in a buffer 212 (FIG. 3) at the client side network element 104. If the bit rate of incoming IP packets exceeds a predefined level, the IP packets are delayed in the buffer to keep the bit rate at the predefined level.

[0032] FIG. 4 is a schematic diagram of a structure of an OSI packet 400 having an encapsulated IP packet 402. The OSI packet 400 can be transferred within the OSI optical network from one network element to another. Every OSI packet 400 includes an origination address 404 and destination address 406. An OSI packet may contain any data that is to be transferred through the OSI optical network 100. In the example shown, the OSI packet contains the encapsulated IP packet 402. The IP packet 402 also

includes an origination address 408 and a destination address 410.

[0033] The network elements are provisioned with a look-up table to track packets that are sent and received. FIG. 5 shows an example of an embodiment of the look-up table. The look-up table 210 stores information about addresses of received OSI packets that encapsulate an IP packet and include columns for origination 508 and destination 508 addresses of the IP devices; the origination 512 OSI addresses of the network elements that originate and terminate the OSI messages and a timestamp 506. The timestamp 506 is used to track connection activity so that aborted or terminated sessions can be deleted from the table after a predetermined interval of inactivity.

[0034] The record 516 illustrates an example of information that is recorded in the look-up table 210 by the network element 104 when it received and processed the first IP packet. The cells 520 and 522 of the record 516 contain information about the destination and origination addresses of the first IP packet. That information is extracted from the IP packet header. The cell 518 contains the origination address of the network element 104. The cell 522 is a timestamp that stores the actual time of the last update to the record 516.

[0035] The record 524 is an example of a record in which all of the cells 526, 528, 530, 532 and 534 are filled. The record 524 includes all the information required to deliver IP packets associated with a particular connection. The record 524 illustrates an example of a record in the look-up table 210 of a network element 104, 110 (FIG. 2) after the destination OSI address has been determined. The

records in the look-up table on the client side network element 104 and the server side network element 110 are associated with the same IP addresses. Of course, the origination address of the OSI and IP packets in the look-up table record on the client side network element 104 are the destination addresses in the look-up table record on the server side network element, and vice versa.

[0036] To better understand the processing of incoming packets at the network elements 104 and 108 depicted in FIG. 2 and FIG. 3, FIGs. 6A and 6B provide a flowchart of the steps that are performed at the respective network elements. Each network element in the OSI network is adapted to receive and process packets. After beginning at step 602, the network element waits for incoming packets. In step 604, when the network element receives a packet, the network element determined the type of packet that was received. In step 606, the network element determines whether the incoming packet is an OSI or a non-OSI packet. If the incoming packet is an OSI packet, the network element performs steps shown in FIG. 6B beginning at connector A. If the incoming packet is an IP packet (step 608), then that packet in step 612 will be encapsulated in the OSI packet. If it is determined that the incoming packet is not an IP packet, the packet is discarded (step 610). To deliver the incoming IP packet to the destination address of the IP packet, it is necessary to originate the OSI address of the network element that serves the IP device that has the IP address in the destination address field of the IP packet to be delivered. In step 614 the destination IP address is searched in the look-up table at the network element. If the destination IP address does not match any records, the address along with a timestamp is written (step 616) in the look-up table. If

the destination IP address is located in the look-up table, in step 618, the look-up table is searched for the presence of the OSI address of the network element that serves the destination IP address. If the OSI address is found in step 618, the OSI packet is sent to the OSI address stored in the look-up table. If the look-up table does not contain the OSI address, the OSI packet encapsulating the IP packet is broadcast to all network elements that support a TCP/IP gateway. As explained above, each record in the look-up table includes a timestamp. The timestamp is used to track the activity of connections tracked in the look-up table. The timestamps of all records in the look-up table at the network element are periodically inspected (step 624). Any record having a timestamp that was last updated more than a predetermined time ago (10 minutes, for example) is deleted from the table.

[0037] As explained above, if the network element determines, in step 606, that an incoming packet is an OSI packet, in step 626 the network element determines whether the OSI packet encapsulates and IP packet. If the OSI packet does not encapsulate an IP packet, the OSI packet is forwarded to the destination address of the OSI packet (step 628). If the OSI packet encapsulates an IP packet, the OSI destination/origination addresses are extracted in step 630; the IP packet is removed from the OSI packet (step 632); and the IP destination/origination addresses are extracted in step 634.

[0038] In step 636, the extracted destination/origination IP addresses are searched for in the look-up table. If in step 686 it is determined that the destination/origination IP addresses do not match any records, a new look-up table record is created and the destination/origination IP

addresses of the IP packet are written to the table in step 637. If the destination/origination addresses are located in the look-up table, the table record is examined to determine whether the OSI origination address has been recorded in the look-up table (step 638). If not, the OSI origination address is recorded in the table (step 640. Otherwise, if it is determined in step 638 that a record that matches the destination/origination IP addresses also contains an OSI address that is associated with the origination address of the IP packet, then the timestamp is updated (step 642) the IP packet is forwarded to the destination IP device, in step 644, and the process ends (step 646).

[0039] The invention therefore provides a simple, effective, economical solution for permitting TCP/IP connections to be set up across an OSI optical network. Network administration and other data communications functions are thereby enhanced.

[0040] The embodiments of the invention described above are intended to be exemplary only. The scope of the invention is therefore intended to be limited solely by the scope of the appended claims.